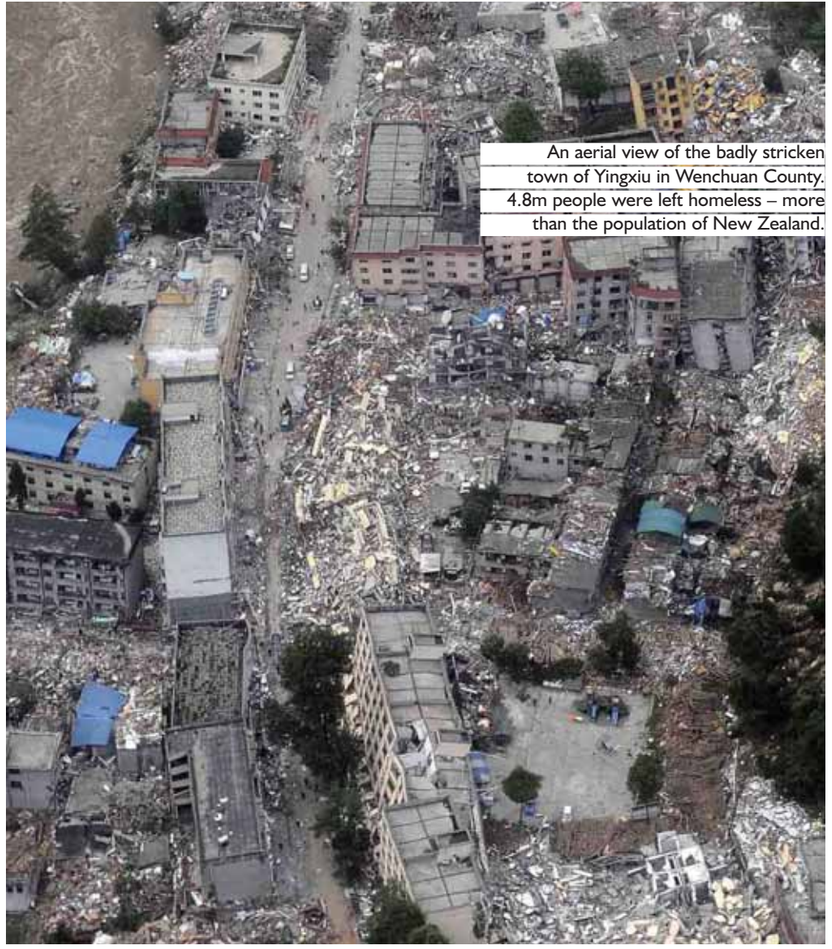
A resident hurries for safer ground as the Tangjiashan 'quake lake' forms in Beichuan county, southwest of China's Sichuan province.



An aerial view of the badly stricken town of Yingxiu in Wenchuan County. 4.8m people were left homeless – more than the population of New Zealand.

THE LONG MARCH TO RECOVERY

Authorities in China have come under fierce criticism for allowing substandard buildings in seismic zones but, as **David Smith** reports, others praise the government for a committed and masterful response which puts not only Burma to shame for its handling of Hurricane Nargis but the US as well, for its handling of Hurricane Katrina

China was always supposed to take the centre of the world stage in August with the Beijing 2008 opening ceremonies, but it happened earlier than anticipated.

Natural disasters have a habit of throwing the best-laid plans into disarray. The massive earthquake which struck Sichuan province on May 12 thrust China into the global spotlight, but in the most traumatic of circumstances.

A race against time unfolded on TV screens worldwide to save lives and provide shelter for millions of homeless people. The Chinese government faces a reconstruction programme on a scale never before seen in history.

Professor Lin Shao Pei, a professor of civil engineering at Shanghai Jiao Tong University and Director General of the Institute of Civil Engineers in China, gives a daunting assessment of the challenge.

"There needs to be a comprehensive plan to guide the engineering. It is very urgent," he says. "There are many special problems because the topographical situation in the high mountains is always changing. Aftershocks can provoke huge landslides that cause storms of rocks to block roads or rush downriver to form new reservoirs, which can wash away communities. It is very tough, a very strict challenge between man and nature."

The first task, he explains, is to repair Sichuan's devastated infrastructure. The county highways were poor to begin with and need replacing. Oil and gas pipelines need repairing. There must be new high-mountain bridges and tunnels.

"This is a very tough problem in rough terrain," he says. "The situation is almost unimaginable. Lots of reconstruction machinery cannot even enter the area. To explore the tops of reservoirs they need helicopters. To get in to the disaster area, teams are spending two or three days travelling 20km. They have to climb over big boulders. It is impossible for any car to get there."

Despite the difficulties, the professor remains optimistic. "The infrastructure will be repaired within one year," he says adamantly, as though there is simply no alternative.

A comprehensive plan is required. To that end, a select team of engineers, town planners and architects have descended on Sichuan from all over China to produce one. They are a highly secretive lot and are unlikely to release any details until late September.

The task of reconstruction is monumental, but British engineer Geoffrey Mills, a part-time company director of Sino Infrastructure Partnership and the Institution of Civil Engineers' representative in China, believes the government will surmount all difficulties.

One reason for his faith is China's new openness, manifested in its willingness to welcome expertise from all over the world. He himself has been invited by the China Society for Civil Engineers to visit Sichuan in August and report on progress.

Temporary housing under construction. 'Just go and we'll settle finances later,' government told big building firms.

PA PHOTOS

LEADERSHIP FROM THE TOP

"The Chinese government has done a wonderful job so far and will continue to do so," says Mr Mills, who has lived in China for 20 years. "They took charge within hours of the disaster. They initiated a three-stage response of, firstly, saving lives, then building temporary homes and, finally, permanent reconstruction. The premier visited the site straightaway and said all the right things. Luckily, he is a distinguished engineer so he had the right background to deal with the situation.

"China's reaction was especially impressive when you compare the slowness of the US response to Hurricane Katrina's devastation in New Orleans, or the reluctance of the Burmese government to accept outside help after the recent cyclone."

The earthquake struck at 14:28 along the Longmenshan Fault and was measured at 8.0 by the China Seismological Bureau and 7.9 by the US Geological Survey. The epicentre was 80km northwest of Chengdu, the capital of Sichuan, at a depth of 19km. Tremors were felt 1500km away in Beijing and 1700km away in Shanghai, and as distant as Vietnam and Thailand.

To date, more than 69,000 people have been confirmed dead, including 158 relief workers killed in landslides. Nearly 400,000 were injured and more than 18,000 people are missing. The earthquake left about 4.8 million people homeless, more than the entire population of New Zealand.

As if the initial earthquake had not caused enough destruction, 52 major aftershocks were recorded within 72 hours, including a 5.7 in Ningqiang in Shaanxi Province, which caused 420,000 homes to collapse. There will be a heightened risk of aftershocks for several months.

Infrastructure damage was severe. All of the highways into Wenchuan and others throughout Sichuan province were damaged. In Beichuan county, 80% of the buildings were razed, according to Xinhua News. In the city of Shifang, the destruction of two chemical plants led to leakage of some 80 tonnes of liquid ammonia, with hundreds of people buried. A total of 391 dams, mostly small, were damaged.

BY JUNE 15, SCG HAD COMPLETED 25,000 CABINS AT A RATE OF ABOUT 400 A DAY

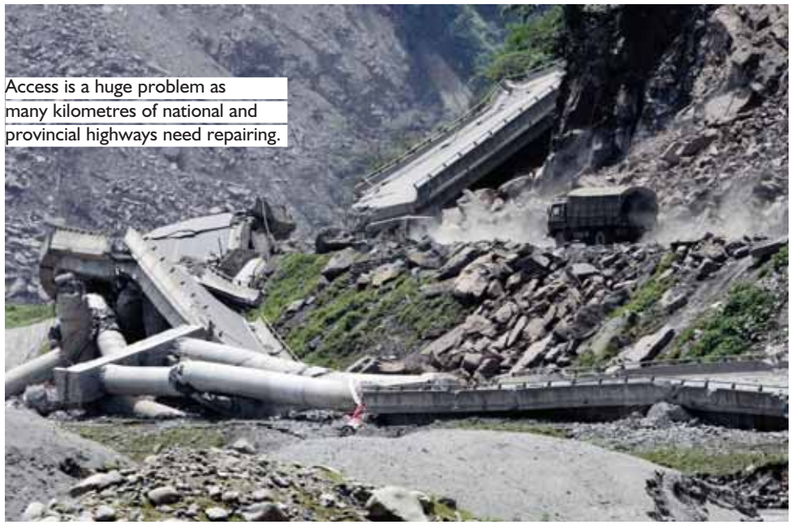
Many schools bore the brunt. In the city of Dujiangyan, the Juyuan Middle School crumbled burying 900 students and killing 50. The school, with its many buried teenagers, was excavated by civilians and cranes.

Telecommunications systems collapsed. China Mobile had more than 2300 base stations suspended. Half of the wireless communications were lost in Sichuan.

Faced with disaster on such a colossal scale, President Hu Jintao announced that the response would be rapid and comprehensive. And he was proved right. Just 90 minutes after the earthquake Premier Wen Jiabao flew to the site to oversee the rescue work.

Wen appealed for the nation to rally together. "This is an especially challenging task," he said. "In the face of the disaster, what is most important is calmness, confidence, courage and powerful command."

In the following days the rescue efforts of soldiers, helicopter crews and foreign aid workers were hampered by persistent rain, but Francis »



Access is a huge problem as many kilometres of national and provincial highways need repairing.

House building in Yingxiu Township, Wenchuan County. Basic shelter is an immediate priority for millions.

» Marcus of the International Federation of the Red Cross praised China's response as "swift and very efficient".

Geoffrey Mills said: "On day one the government sent the two biggest construction companies, Shanghai Construction Group (SCG) and Shanghai Urban Construction Group (SUCG), to the area. The response was so fast it was wonderful. The Government said 'just go there now', and we'll discuss the finances later. SCG had 120 engineers on-site within a week. A swift response to an emergency is one advantage of China's political system."

INSTANT LAKES

The government reacted promptly to avert potential follow-on calamities. One of the most serious was the formation of quake lakes as landslides blocked rivers. The flood threat from these ad hoc dams endangered millions of people and entire villages had to be evacuated. The most precarious quake lake was at Lake Tangjiashan in the heavily damaged town of Beichuan. Soldiers used explosives on June 9 to divert the water after the evacuation of more than 250,000 residents.

After two weeks, the fight to save lives and house survivors in tents was still continuing as the government embarked on the second stage of its programme, a massive project to build one million small, temporary homes before August 10.

These 20m² cabins are made of lightweight steel, plywood and other recyclable materials, and are earthquake-proof. They will house survivors for three to five years while workers build permanent homes. For every thousand cabins the government has promised a primary school, a clinic and a supermarket.

Mr Mills was impressed by the speed of progress. "By June 15, SCG had completed 25,000 cabins at a rate of about 400 a day. Urban CG were putting up a similar number. It was very impressive stuff from these companies."

All the operations were costly. The government set aside 70 billion yuan (US$10 billion) for reconstruction in 2008 and the Cabinet came up with a scheme for the wealthiest areas to fund recovery.

It ordered 19 of China's best-off provinces and cities to provide aid for the 20 hardest-hit Sichuan regions on a one-to-one basis – except Guangdong, the province with the highest gross domestic product, which was assigned the two worst-hit regions: the epicentre of Wenchuan County and Gansu Province.

Each rich region must offer aid worth at least 1% of its year-earlier fiscal revenue to its 'adoptee' region for three years. Benefactors should also send experts to help with plans and training and they must donate machinery.

Shanghai was assigned the devastated Dujiangyan City. It immediately handed over seven police vehicles and other equipment to Dujiangyan's public security department. It has also promised to build a 4820m² temporary office space and provide communication systems worth more than 10 million yuan (US$1.45 million).

THE SITUATION IS ALMOST UNIMAGINABLE. LOTS OF RECONSTRUCTION MACHINERY CANNOT EVEN ENTER THE AREA

A further issue to be dealt with by the Chinese government was the harsh criticism of much of the building work in Sichuan. Experts disagreed on whether the building codes were adequate, though most thought they were. Many felt the problem was that the codes had not been followed, or that workmanship was poor. Some of the strongest criticism came out of California.

"A 7.9 earthquake will cause some loss of life, but it doesn't have to trap 900 children in a school, or kill thousands of people. We can prepare better than that," Dan Shapiro, a San Francisco structural engineer and former member of the California Seismic Safety Commission, told the *San Mateo County Times*.

Some critics have argued that building regulations did not adequately protect schools, at least eight of which were destroyed. They point to the three classes of seismic reinforcement. Class 1, the most protected, includes airports and nuclear reactors. Class 2 includes some hospitals, low-rise nurseries and large elementary schools. Buildings in class 3, requiring ordinary seismic requirements, are most schools and flats.

This has become the most emotive issue in China. The collapse of an estimated 7000 schoolrooms caused a major outcry and thousands of parents accused officials and builders of cutting corners in school construction. They demonstrated loudly and demanded an investigation.

The government was forced to make a gesture to placate angry parents and its National Development and Reform Commission drafted an amendment to improve construction standards for primary and middle schools in rural areas. It also launched a probe into the deaths of 1300 pupils and teachers in the collapse of Beichuan Middle School, in Mianyang city.

The criticism levelled at Chinese construction infuriates Geoffrey Mills. "Flimsy structures?" he says. "If you go back 20 years none of China's modern infrastructure existed. The construction of modern China has been a very successful project on an unprecedented scale. China has pulled itself up by its bootstraps.

"It's had to write codes, license them and train engineers in a few years. It's been so helter skelter that weaknesses are inevitable. If the buildings had not gone up so fast there would be more poverty and fewer schools.

"This earthquake took place in the back of beyond. Most schools were made of pre-cast concrete and put together like Meccano sets. They can be well-constructed, but you need good skill levels from artisans. It's asking a lot of a nation of 1.3 billion to all be pulling in the same direction and be 'well-educated'.

"In reality, a category 8 earthquake will unearth weaknesses even in societies with mature construction practices. If you take a country of 1.3 billion and turn it from an agrarian society into the world's third biggest economy in a generation, a few cracks will be exposed."

Mr Mills added that China should not overreact to the criticism and should take a broader philosophical view.

SAFER FOR CHILDREN

"If they started making every building safe for category 8 earthquakes everywhere in China, they would run out of resources pretty quickly. Some perspective is needed. They must not overreact. They can't spend all the money ensuring every column and every beam is thicker. A careful response is required, not a gut reaction."

The government is still working out its response though it has promised to pass stricter laws on earthquake-resistant construction after an intensive investigation. The government has also promised to approve a corps of independent engineers to inspect buildings nationwide, and begin retrofitting unsafe schools across China.

But others say it doesn't have to cost the earth to help schools absorb seismic shocks. Brian Tucker, the president and founder of GeoHazards International, an organisation that works to improve building codes worldwide, claims the cost of quake-resistant schools is only slightly higher.

"In polls conducted across the world, people say they are willing to spend more to make sure schools are safe for kids during earthquakes," Mr Tucker says. His group will join a China-based reconstruction project being considered by the Organisation for Economic Co-operation and Development (OECD), to build structures such as hospitals and schools that will remain standing after an earthquake.

No matter what codes are written or rewritten, China must improve the skills of thousands of its tradesmen to make sure procedures are followed. One organisation which could help in this respect is the World Housing Encyclopedia (WHE). This web project disseminates information worldwide on creating quake-resistant structures.

"Adobe and other forms of unreinforced masonry construction are proven 'serial killers' in many earthquakes worldwide," Svetlana Brzev, WHE's co-founder and an engineer at the British Columbia Institute of Technology in Canada, told National Geographic News. "Unreinforced masonry seems to be a culprit in the earthquake-affected area in China."

Ms Brzev argues that popularising WHE's simple manuals, or similar works, across China could improve enormously the skills of tradesmen.

Better codes and skills will help, of course, but there is no better protection for key buildings, than to locate them away from the faultlines.

Desks in a ruined school in Dujiangyan.

Dr Alex Densmore, of the Institute of Hazard and Risk Research at Durham University, who co-authored a study of Sichuan's tectonic faults 12 months ago, argues that a buffer zone around the faultline is essential. He says that schools and hospitals should not be built within a critical distance of the faults, nor should any high-density population building be placed in a landslide hazard zone.

MOVE CHENGDU?

Dr Densmore believes a buffer zone could reduce earthquake fatalities by one or two degrees of magnitude. "Instead of tens of thousands of people dying, maybe thousands or hundreds will die," he says.

"The salient question is how much money China can afford to spend on reconstruction," he added. "If money were no object they could rebuild the whole province to withstand a category 8 earthquake. I don't know if that money is there, plus there are lots of other areas at risk in China.

"It makes sense to relocate key buildings, or even cities. The government is considering rebuilding the capital, Chengdu, in a different place. If it is moved 20 km nearer a low-relief plane, it will be much safer. They may have to forceably move some people, but it will be away from the steep slopes where landslides cause most of destruction."

The reconstruction process, though costly, is stimulating demand. Sinotruk, the biggest truck manufacturer in China, has already received government orders for more than 1000 vehicles and plans to lift its capacity by a third in 2009.

Ma Chunji, the head of Sinotruk, told the *International Herald Tribune*: "It's a sad thing. But it will stimulate demand. Beijing planned originally to readjust the speed of growth and compress the size of infrastructure projects, and that would have affected us. Now we face a positive."

The direct role of private companies in the reconstruction process is less clear, though Geoffrey Mills believes they will have a large part to play. "The Chinese economic structure is increasingly in private control with a lot of state influence. There are lots of shareholders in the major construction companies and construction is well-regulated. There are more and more listed companies.

"Ultimately, once the plan is in place, the long-term reconstruction work will all go out to tender and the best tendering will win contracts. The money from stage two is all dead money. The rough pre-fabs have no longevity and China's companies will want to get the long-term programme up and running as soon as possible and switch into real asset investment."

Professor Lin Shao Pei is not so convinced that private companies will play such a major role. "Big donations have come from private companies, but when it comes to carrying out the work, all the resources are controlled by central government. Each county is supported by specific central urban planning and private companies can't take over. The materials are too tightly related to government actions. Private companies won't find it easy to manoeuvre."

Foreign companies also see the reconstruction process as an opportunity. Many British firms have offered help, including Atkins and Arup.

Atkins' staff have donated 300,000 yuan and offered a package of building designs. The company has five experts in Pengzhou, in Sichuan, helping to assess damage to schools.

Arup have a team of structural engineers on the ground doing damage assessment. The company helped design and build some schools in Gansu province that have been damaged and wants to repair the structurally deficient ones.

Arup are also planning seminars for engineers about safety assessments and for architects on designing earthquake-resistant buildings.

China's openness to outside help means the expertise will be embraced. It remains to be seen how open China will be to giving foreign companies the major roles in the reconstruction process they seek. *ICON*

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